A COMPARISON OF INFLATABLE AND SEMI-RIGID DEPLOYABLE AERODYNAMIC DECELERATORS FOR FUTURE AEROCAPTURE AND ENTRY MISSIONS

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With the successful flight of Inflatable Reentry Vehicle Experiment-II, the concept of using fabric-based aerodynamic decelerators has been demonstrated. This flight was a ballistic entry from a sub-orbital velocity. Now, with the imminent launch of the Mars Science Laboratory and its guided lifting aeroshell, the bar has been raised for all future aerodynamic decelerator systems. Once this technology has been successfully demonstrated, future science missions will demand precision landing from any entry system, including future deployable aerodynamic decelerators. This paper will compare and contrast the system performance and capabilities of the two main classes of deployable aerodynamic decelerator, the inflatable and the semi-rigid deployable, with the goal of showing equal or greater performance to the existing state-of-the-art rigid aerodynamic decelerator.

The current state-of-the-art for Mars entry system uses a rigid aeroshell for hypersonic deceleration, a disk-gap-band parachute deployed near Mach 2.0, and either airbags or chemical propulsion for terminal descent. This entry architecture is representative of all the successful United States Mars missions flown to date, with a maximum entry mass less than 1000 kg (590 kg payload) and landed altitude of -1.4 km referenced to the Mars Orbital Laser Altimeter (MOLA). With the successful flight of the Mars Science Laboratory (MSL) the envelope will be extended to nearly 3000 kg entry mass (800 kg payload) and +2.0 km MOLA landing altitude. Braun and Manning[i] show that this is very near the limit of the current landing architecture, and that new technology will be needed for larger missions. One option for this new technology is the deployable aerodynamic decelerator, which prior studies have shown offers substantial mass advantages to rigid systems at Mars and other destinations with an atmosphere for both entry and aerocapture[ii,iii]. Furthermore, deployable systems promise a much broader range of landing altitudes and entry masses that support human exploration.

There are multiple deployable aerodynamic decelerator concepts that can be divided into two primary classes: inflatables, and semi-rigid deployables. The two main classes of deployable aerodynamic decelerator have been compared for both aerocapture and entry at Mars using ballistic trajectories, and their entry system mass fractions were shown to be within 2%[iv]. With such similar mass performance, other metrics such as precision landing capability, resistance to micrometeoroids, and operational flexibility should be considered when planning future technology investments in aerodynamic decelerators.

This paper will draw from the results of the High Mass Mars Entry Systems study, the Aerocapture GN&C study, and other previously unpublished work performed at Ball over the past 3 years. The result shows that the inflatable and semi-rigid deployable configurations are quite closely matched. Given the comparable overall desirability of these systems, future studies should include both concepts to minimize risk while developing the next generation of aerodynamic decelerator systems.

[i] Braun, R.D., and Manning, R.M., “Mars Exploration Entry, Descent, and Landing Challenges,” *Journal of Spacecraft and Rockets*, Vol. 44, No. 2, pp. 310-323, 2007.
[ii] Miller, K.L., et al, “Trailing Ballute Aerocapture – Concept and Feasibility Assessment,” AIAA Paper 2003-4655, 39th AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, Huntsville, AL, July 2003.
[iii] Zang, T.A., et al, “Overview of the NASA Entry, Descent and Landing Systems Analysis Study,” AIAA Paper 2010-8649, AIAA Space 2010 Conference and Exposition, Anaheim, CA, Aug. 30-Sep. 2, 2010.
[iv] Rohrschneider, R.R., “High Mass Mars Entry System Final Report,” Unpublished final report of contract NNL08AA34C, 2010.